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The Connecticut Valley-Gaspe Synclinorium in Southernmost Vermont

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THE CONNECTICUT VALLEY-GASPÉ SYNCLINORIUM IN SOUTHEASTERNMOST VERMONT

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INTRODUCTION

In southeastern Vermont the regionally extensive Connecticut Valley-Gaspé synclinorium separates the Bronson Hill anticlinorium, with its Oliverian gneiss-cored domes, to the east from the Green Mountain anticlinorium to the west (Doll and others, 1961). This synclinorium is principally underlain by a thick sequence of late Ordovician, Silurian and early Devonian flysch and calcareous flysch and minor, but important, interbedded mafic volcanics. These rocks have undergone variable degrees of metamorphism (chlorite to kyanite zones) and have been multiply folded and intruded during the Acadian Orogeny. A belt of domes, occurring in the Connecticut Valley-Gaspé synclinorium, extends southward from east-central Vermont to Connecticut, west of the Connecticut River. They are somewhat analogous to but more widely spaced than the domes of the Bronson Hill anticlinorium to the east. Large recumbent folds are found in the strata mantling these domes in eastern Vermont (Doll and others, 1961). The Standing Pond Volcanics is an important marker unit outlining many of these recumbent folds and domes. The axial surfaces of the recumbent folds have been arched by the later doming. The arcuate, closed, double band of the Standing Pond Volcanics around the southern end of the Guilford done in southeastern Vermont (fig. 1) outlines such a refolded recumbent fold. One of the purposes of this field trip is to investigate this fold and the proposed east-facing recumbent anticline above it. Other stops will be made to view the Black Mountain Granite, an important key to determining the time of deformation; the Waits River Formation in the exposed core of the Guilford dome; and the contact between the Putney Volcanics and the Littleton Formation, which separates the "Vermont" and "New Hampshire" sequences (Billings, 1956).

This field excursion is an updated version of one led during the 1972 N.E.I.G.C. (Hepburn, 1972). For a more complete description of the geology of the Brattleboro area than can be presented here, detailed geological maps, etc., the reader is referred to Hepburn and others, 1984.

STRATIGRAPHY

Brief descriptions of stratigraphical units pertinent to this excursion are summarized below. For more detailed descriptions of the stratigraphy of this area please refer to Doll and others (1961), Chang and others (1965), and Hepburn and others (1984), and references therein.

The Standing Pond Volcanics forms a distinctive marker formation for mapping and by defination separates the Waits River and Gile Mountain Formations. However, it should be recognized that in southeastern Vermont the Standing Pond Volcanics does not everywhere exactly separate calcareous rock types (characteristic of the Waits River Formation) from non-calcareous rocks (characteristic of the Gile Mountain Formation). Calcareous rocks in the Gile Mountain Formation similar to those in the Waits River Formation have been designated the marble member of the Gile Mountain (fig. 1, Stop 9). The quartzitic member of the Waits River Formation contains schistose and feldspathic quartzites and mica schists, similar to those in the Gile Mountain Formation.

The Putney Volcanics (Stops 1 and 2) consists of a belt of rocks that were formerly included in the Standing Pond Volcanics (Doll and others, 1961) but now is designated as a separate formation (Trask, 1980).

Determination of the stratigraphic order of the rocks in the "Vermont" sequence has been a long standing problem. No definitive evidence for the facing of the Waits River, Standing Pond, and Gile Mountain formations has yet been found in southeastern Vermont. However, Fisher and Karabinos (1980) reported good stratigraphic topping evidence near Royalton, Vermont, that indicates the Gile Mountain is younger than the Waits River Formation. Thus, the sequence, oldest to youngest, of Waits River, Standing Pond, and Gile Mountain, as shown on figure 1 is favored, although other possibilities can not be ruled out.

Good stratigraphic topping evidence has been found in the Brattleboro quadrangle at several sites within the Putney Volcanics and at its contact with the Littleton Formation (Hepburn and others, 1984). This evidence based on small cross-bedded sequences, consistantly indicates that the stratigraphy gets younger to the east across this contact, i.e. that the Littleton overlies the Putney (Stop 2). This implies the package of rocks between the Shaw Mountain Formation and the Putney Volcanics, the "Vermont" sequence, is pre-Littleton (Early Devonian) in age. Recently, Bothner and Finney (1986) reported the recovery of Middle to Upper Ordovician graptolites from the Waits River Formation near Montpelier, Vermont. Thus, the age range of the "Vermont" sequence likely spans the time from middle or late Ordovician to earliest Devonian. However, because temporal boundaries have not yet been established for this sequence of rocks, they are herein (fig. 1) labeled Silurian, conforming with Hepburn and others (1984).

Stratigraphic units in southeastern Vermont (Brattleboro quadrangle) include:

MIDDLE ORDOVICIAN

Barnard Volcanic Member, Missisquoi Formation: Massive to schistose porphyritic and non-porphyritic amphibolites, feldspar-rich gneisses, and layered gniesses. Thickness, 4000-8000 feet.

Cram Hill Member, Missisquoi Formaton: (Following Doll and others, 1961.) Rusty-weathering, black carbonaceous phyllite and schist with interlayered amphibolite. Thickness, 2000-4000 feet.

SILURIAN (May include in part, middle to late Ordovician and/or early Devonian)

Shaw Mountain Formation: (Russell Mountain Formation of Hepburn and others, 1984) Quartzite and quartz-pebble conglomerate, hornblende fasciculite schist, amphibolite, and mica schist. Thickness, 0-20 feet.

Northfield Formation: Gray mica schist with abundant almandine porphyroblasts, minor impure quartzite and punky-brown weathering impure marble interbeds. Thickness,1000-2500 feet.

Waits River Formation: Mica schist (phyllite at lower metamorphic grades) and calcareous mica schist with abundant distinctive interbeds of punky-brown weathering impure marble; thininterbeds of impure quartzite. **Quartzitic member:** feldspathic and micaceous quartzite interlayered with mica schist. Formation thickness, 3000-7500 feet.

Standing Pond Volcanics: Medium-grained amphibolite and epidote amphibolite; garnet-hornblende fasciculite schist. **Eastern band:** plagioclase-biotite-hornblende-quartz granulite and gneiss. Formation thickness, 0-500 feet.

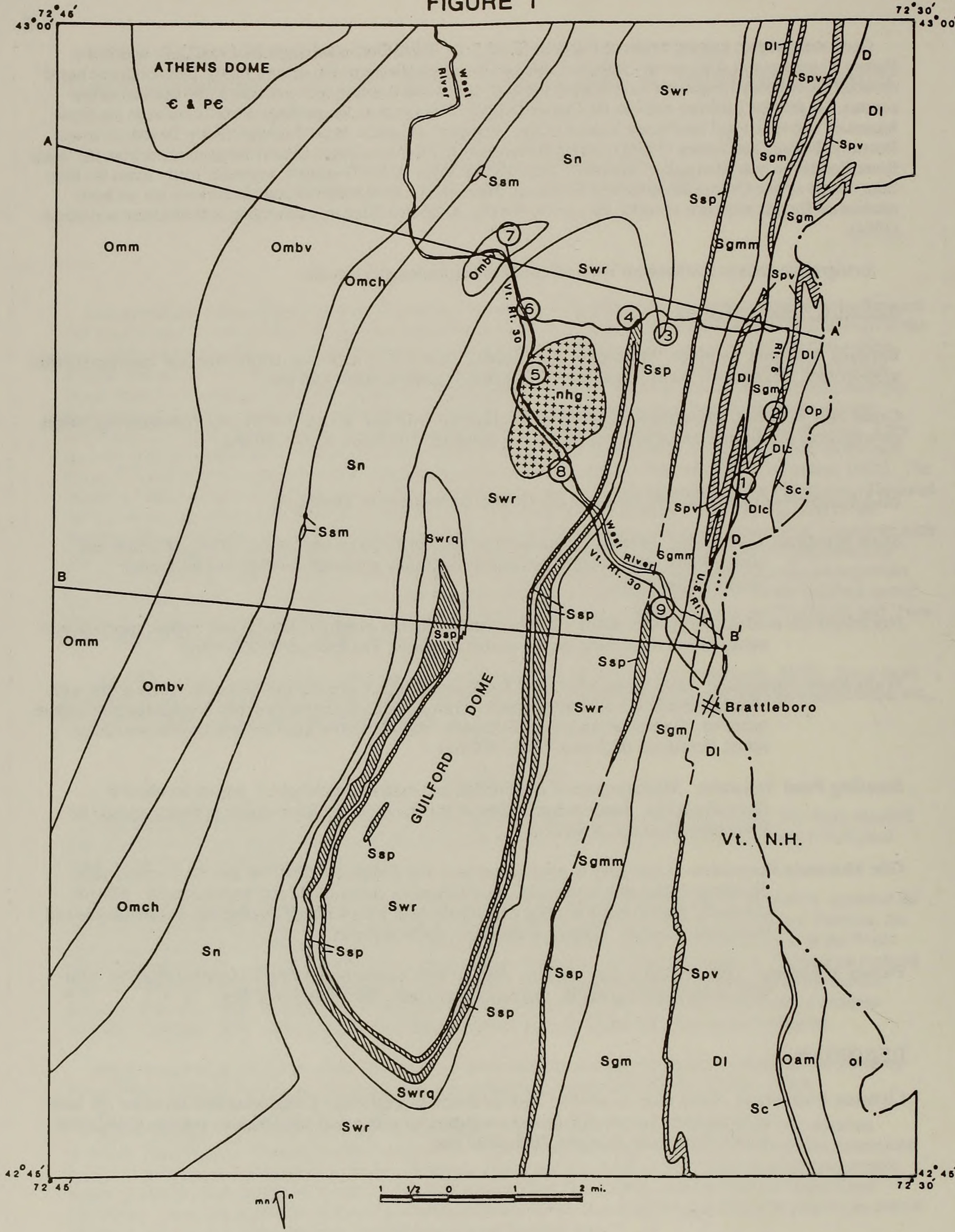
Gile Mountain Formation: Light gray to gray, micaceous and feldspathic quartzite and mica schist; gray phyllite and slate with interbedded, thin micaceous quartzite and rare impure marble. **Marble member:** gray to black phyllite with interbeds of punky-brown weathering, impure marble and micaceous quartzite. Formation thickness, 2500-5000 feet.

Putney Volcanics: Light, greenish gray phyllite; buff to light brown weathering feldspathic phyllite; thin beds of feldspathic granulite; and minor gray slate. Thickness, 0-400 feet.

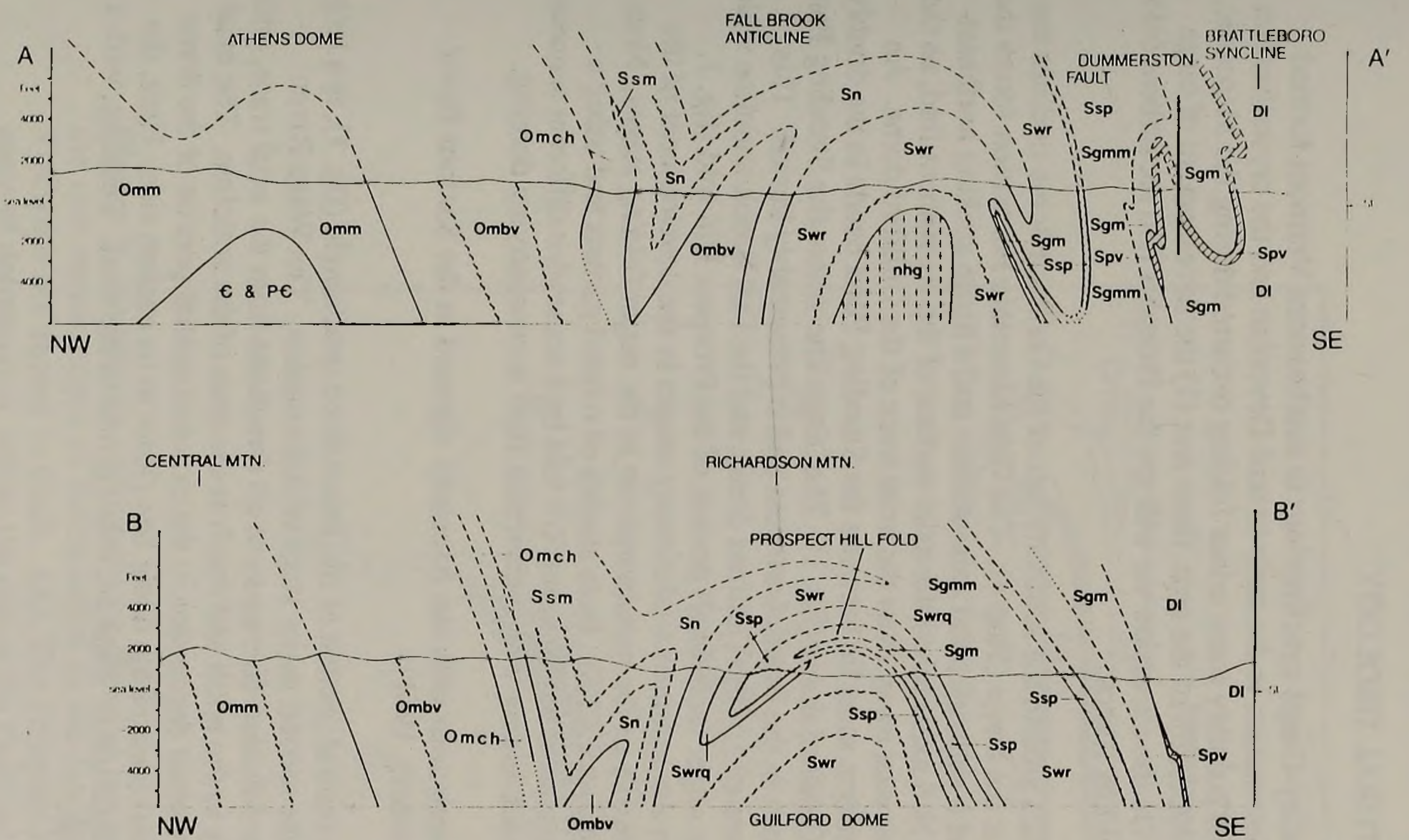
DEVONIAN

Littleton Formation: Gray slate or phyllite with interbeds of quartzite. **Conglomeratic member** (at base of formation): Lenses of polymict conglomerate with a gray slate matrix; pebbles abundant to scarce. Formation thickness, 5000-6000 feet.

FIGURE 1



GEOLOGIC MAP OF THE GUILFORD DOME AREA, SE VERMONT



LEGEND FIGURE 1

METAMORPHIC ROCKS

Dl	LITTLETON FM.	Swr	WAITS RIVER FM.		
Dlc	LITTLETON FM.,congl. mbr.	Sn	NORTHFIELD FM.		
Spv	PUTNEY VOLCANICS	Ssm	SHAW MOUNTAIN FM.	Sc	CLOUGH QUARTZITE
Sgm	GILE MOUNTAIN FM.	Omch	MISSISQUOI FM., Cram Hill Mbr.	Op	PARTRIDGE FM.
Sgmm	GILE MT. FM., marble mbr.	Ombv	MISSISQUOI FM., Barnard Volc. Mbr.	Oam	AMMONOOSUC VOLC.
Ssp	STANDING POND VOLC.	Omm	MISSISQUOI FM., Moretown Mbr.		
Swrq	WAITS RIVER FM., qtzt. mbr.				

PLUTONIC ROCKS

nhg	NEW HAMPSHIRE PLUTONIC SERIES
	Black Mt. Granite
ol	OLIVERIAN PLUTONIC SERIES

D — Fault, D on Downthrown side

(3) — Field Trip Route & Stop

Geology and Cross Sections Modified after

Hepburn, Trask, Rosenfeld, and Thompson, 1984

INTRUSIVE ROCKS

Black Mountain Granite: Medium-grained garnet bearing two mica granite to granodiorite. Hayward and others (1988) recently determined a Carboniferous crystallization age of 326 ± 17 Ma (Rb-Sr whole rock) for the Black Mountain Granite. Shields (1977, see also Hepburn and others, 1984) gravity study of the Black Mountain Granite indicates the body extends for 5 km below the current surface and was intruded more or less along the steeply west dipping axial surface of the Guilford dome with a nearly vertical eastern contact and a western contact dipping approximately 55°.

STRUCTURAL GEOLOGY

The major tectonic features in the Connecticut Valley-Gaspé synclinorium in southeastern Vermont formed during the Acadian Orogeny, between the end of sedimentation in the early to mid-Devonian and the crystallization of the Black Mountain Granite. Late normal faulting and possibly some minor folding occurred during the Mesozoic. Two major stages of folding dominate the structural evolution of the area, these are: (1) the development of large recumbent folds, followed by (2) the rise of domes. On the excursion we will see the Prospect Hill recumbent fold and the Guilford dome as examples of these major folding stages.

The doubly-closed loop of Standing Pond Volcanics around the southern part of the Guilford dome outlines the Prospect Hill recumbent fold, named for exposures at the hinge (Stop 4). The Gile Mountain Formation forms the core of the fold. Originally the Prospect Hill fold had a subhorizontal axial surface and a hinge striking northeast-southwest. The subsequent doming about a roughly N-S axis arched the axial surface of the recumbent fold, so that now the hinge plunges moderately northeast and southwest away from the axial trace of the Guilford dome. An early, tight, now overturned, steeply east-dipping synform must lie between the Standing Pond bands in the doubly-closed loop and a third band lying to the east of the Guilford dome (fig. 1). The hinge line where the Standing Pond rocks cross the axial surface of this synform is not seen in the Brattleboro area and is presumably buried. This synform, the Northfield Formation around the northern end of the Guilford dome, and the Fall Brook anticline which exposes the Barnard Volcanics, are interpreted as the upper (anticlinal) portion of the Prospect Hill fold (fig. 1, Cross-section A). Figure 3 shows in schematic form the assumed evolutionary stages in the development of the Prospect Hill fold and Guilford dome and the relationship of the metamorphism to the major folding stages. Note that Rosenfeld (1968, and in Hepburn and others, 1984, p.93-100), from studies of rotated garnets and using a different stratigraphical order than is assumed here, produces the Prospect Hill fold by a somewhat different sequence of events, involving initial westward transport and backfolding with intrastratial flow accompanying doming.

It is very likely that the Prospect Hill fold is continuous with the Ascutney sigmoid in the Saxtons River quadrangle to the north (Rosenfeld, 1968; Doll and others, 1961).

The Guilford dome, which occupies much of the central portion of the Brattleboro quadrangle (fig. 1), is a large, elliptical, doubly-plunging anticline formed during the second major stage of deformation. The Waits River Formation forms the exposed core of the dome. The foliation dips away in all directions from the axial trace, which strikes slightly east of north and plunges moderately to the north and south at the ends of the anticline. The axial surface of the dome dips very steeply to the west. A small depression in the exposed central portion of the dome divides it into a northern and southern lobe. The axial trace of the dome lies closer to its eastern side. Here, the foliation has steep dips a short distance east of the axial trace. Dips are more gentle to the west. Bedding, with a schistosity parallel to it, has been arched by the dome.

MINOR FOLDS

Minor folds of at least five different stages are present in Connecticut Valley-Gaspé synclinorium in the Brattleboro area (Hepburn, 1975). These stages of minor folding include:

F_1 Small isoclinal folds in layering, with schistosity developed parallel to the axial surfaces (Stop 4).

F_2 Tight to isoclinal folds congruous with the large-scale recumbent folding (Prospect Hill fold). These fold the schistosity and the F_1 folds and plunge moderately NE or SW. Weak to moderate axial-planar cleavage (Stop 4).

F3 Open folds, particularly west and south of the Guilford dome. Excellent slip-cleavage developed parallel to the axial surfaces. The axial surfaces generally strike NE and dip steeply NW. The hinges plunge moderately NE. Excellent crinkle lineations occur at the intersection of this slip-cleavage and the schistosity surfaces in the pelitic rocks.

F4 Open folds, buckles or warps in the foliation that are of one or more generations and fold the slip-cleavage.

F5 Large open folds found only in the eastern part of the area (fig. 1) that offset the Putney Volcanics with an east-side-north movement. Plunge is moderately to steeply north. Kink bands also found along the eastern part of figure 1 are the youngest minor folds and may be related to the above F5 folds or may be younger.

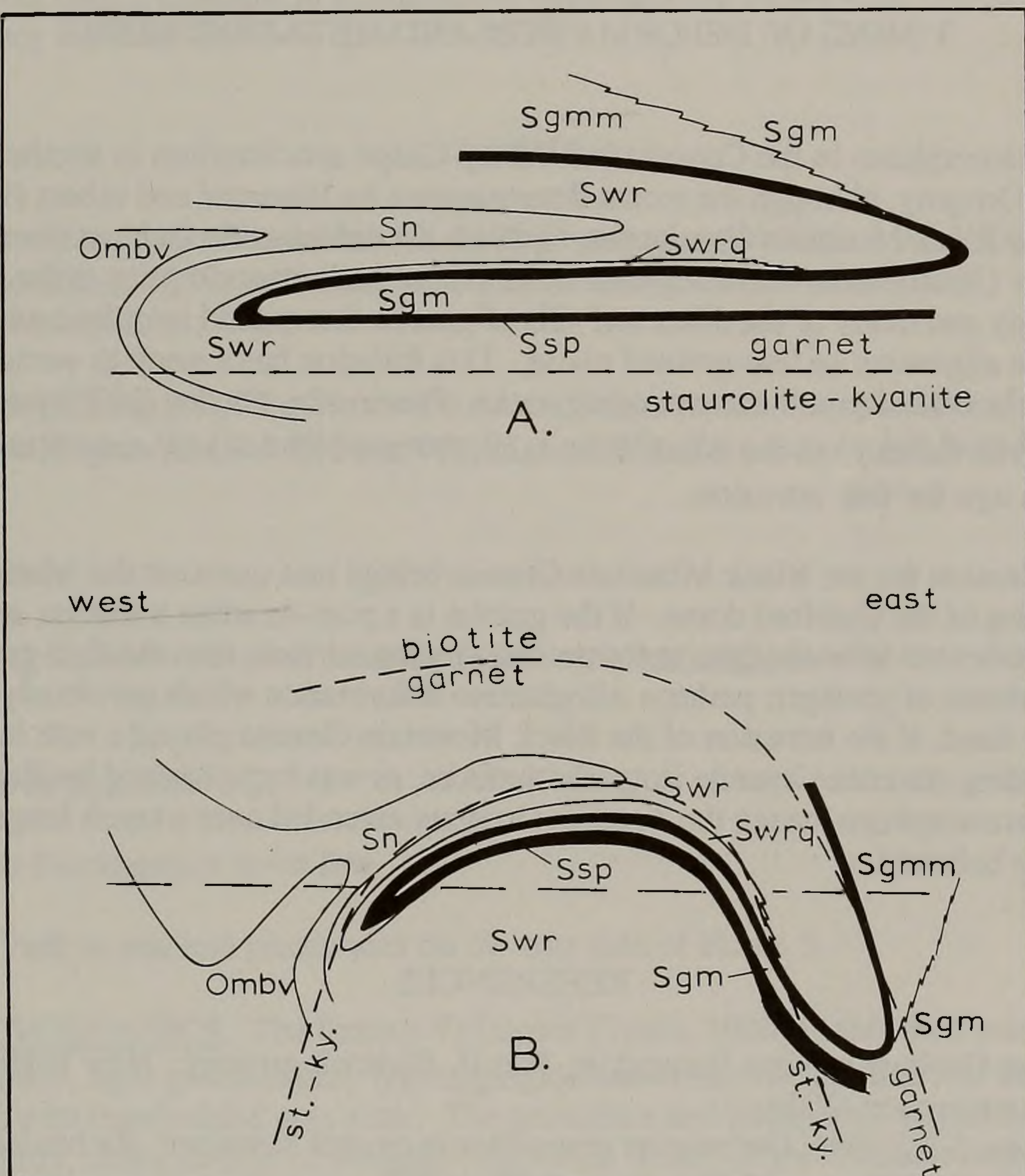


Figure 3. Schematic cross sections showing the evolution of the structural features in the two major stages of deformation in the Guilford dome area. The Standing Pond Volcanics are shown in black. (A). The Prospect Hill fold at the end of the first major stage of deformation, before the rise of the Guilford dome. The dashed line represents a hypothetical staurolite or kyanite isograd. (B). Prospect Hill fold following the second major stage of deformation, after the rise of the dome. Horizontal line represents the present erosion surface. The dashed lines show the assumed present distribution of isograds. Modified after Hepburn and other (1984). Formations: Sgm=Gile Mt. Fm.; Sgmm=Gile Mt. Fm., marble mbr.; Ssp=Standing Pond Volcanics; Swr=Waits River Fm.; Swrq=Waits River Fm., quartzitic mbr.; Sn=Northfield Fm.; Ombv= Missisquoi Fm., Barnard Volcanic Mbr.

METAMORPHISM

A belt of low-grade metamorphic rocks (chlorite zone) occurs in the eastern part of the area and roughly follows the Connecticut River. This low is of regional extent (Thompson and Norton, 1968). It separates the higher grade metamorphic terranes of the Bronson Hill anticlinorium from the belt of higher grade domes of the Connecticut Valley-Gaspé synclinorium in eastern Vermont. The highest grade of regional metamorphism in the synclinorium in the Brattleboro area, staurolite-kyanite zone, is centered on the Guilford dome. Peak metamorphic conditions occurred late in the deformational cycle likely synchronous with and following the later stages of the doming deformation. During the earlier recumbent folding, metamorphic conditions likely did not exceed those of the garnet zone. A small diopside-bearing contact aureole is developed adjacent to the Black Mountain Granite (Stops 5 and 8).

TIMING OF DEFORMATION AND METAMORPHISM

Deformation and metamorphism in the Connecticut Valley-Gaspé synclinorium in southeastern Vermont are assigned to the Acadian Orogeny, although the recent determination by Hayward and others (1988) of a Carboniferous crystallization age for the Black Mountain Granite may indicate the deformation and metamorphism lasted longer than previously thought. Clearly most of the regional deformation had occurred prior to the intrusion of this granite. However, the granite body and many of the dikes and sills of granite that extend into the country rock have a weak foliation produced by the alignment of fine-grained micas. This foliation has a steep to vertical dip and roughly parallels the strike of the schistosity in the surrounding rocks. Previously, Naylor (1971) interpreted the ages of coarse unaligned muscovite flakes from the Black Mountain (377 and 383 $\pm$ 7 Ma, early Middle Devonian) as likely establishing a minimum age for this intrusion.

The new age determination for the Black Mountain Granite brings into question the relation between the timing of its intrusion and the rise of the Guilford dome. If the granite is a post-Acadian intrusion and cross-cuts the dome and surrounding rocks, as seems to be the case at the present erosion surface, then the fine-grained mica alignment in the granite would be evidence of younger, perhaps Alleghanian deformation which previously has not been identified in the area. On the other hand, if the intrusion of the Black Mountain Granite played a role in the rise of the Guilford dome and of the surrounding staurolite-kyanite isogradic surfaces, as was hypothesized by Hepburn and others (1984), then deformation and metamorphism during the Acadian Orogeny extended over a much longer time in southeastern Vermont than previously believed.

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ITINERARY

Maps: Excursion stops will be in the Brattleboro Vt.-N.H. 15 minute quadrange. Geologic maps of the Brattleboro quadrangle (Hepburn and others, 1984) and of the State of Vermont (Doll and others, 1961) are available from the Vermont State Library, Montpelier.

Assembly point is the parking lot of the Howard Johnson Restaurant at the junctions of Routes 5, 9, and Interstate 91 north of Brattleboro Vt. (just off Interstate 91, Exit #3). Cars may be left here for the day and car pooling is encouraged.

Mileage

0.0 Exit parking lot of the Howard Johnson Restaurant, turn right (north) onto Vt. Route 5 at the traffic lights.

0.7 Overpass over Interstate 91.

0.9 Brattleboro-Dummerston town line.

1.2 STOP 1. Park in rest and picnic area on the east side of Route 5.

PUTNEY VOLCANICS. The Putney Volcanics (Trask, 1980) in this area consist of fine-grained, poorly foliated, light greenish gray quartz-plagioclase-muscovite phyllite and laminated granulite (used texturally) with interbedded gray slate. The granulites and feldspathic phyllites weather buff to light brownish gray, characteristic of feldspar-rich rocks. Many of the foliation surfaces have a notably silky sheen. Small, brownish pits where carbonate has weathered out are common. A few lenses of quartz-pebble conglomerate assigned to the Littleton Formation may be seen along Route 5 south of the highway pull-off but are much better developed at Stop 2. The rocks have been metamorphosed to the chlorite zone at this locality.

Continue north on Route 5.

1.4 Outcrop of Putney Volcanics to the east.

1.5 Outcrop of Putney Volcanics to the west.

2.1 Slate quarry in the Littleton Formation to the east.

2.3 STOP 2. Park on left (west) side of the road in small highway pull-off.

CONGLOMERATIC MEMBER, LITTLETON FM. & PUTNEY VOLCANICS. First examine outcrops of gray slate in the Littleton Formation on the east side of Route 5. Then cross Route 5 and walk approximately 0.1 mile north through woods to an abandoned chicken-yard near houses. (The chicken-yard has become increasingly overgrown in recent years since the chickens flew the coop.) Here the conglomeratic member of the Littleton Formation is exposed along with the phyllites and feldspathic granulite interbeds of the Putney Volcanics, immediately west of the conglomerate. The conglomerate contains both quartzite and slate pebbles in a slate matrix. (As this is the best exposure and type locality for the conglomerate, NO HAMMERING--PLEASE!)

The contact of this conglomerate with the Putney Volcanics represents the division between the "Vermont" and "New Hampshire" sequences in this area and has often been referred to informally as the "Chicken Yard line," named for these exposures. Cross bedding in laminated feldspathic granulitic beds of the Putney very near its contact with the Littleton Fm. at this locality (see if you can find them) and elsewhere in the Brattleboro quadrangle, along with possible load casts and apparent channeling in the conglomeratic beds of the Littleton (see Hepburn and others, 1984) consistantly indicate that the stratigraphy gets younger to the east, i.e. that the Littleton overlies the Putney. This implies the package of rocks between the Shaw Mountain Fm. and Putney Volcanics, the "Vermont" sequence, is pre-Littleton in age, likely late Ordovician or Silurian to earliest Devonian. Hepburn and others (1984) suggest the contact between the Putney and Littleton Fms. as exposed here is possibly an unconformity. However, an alternative interpretation that this contact represents a major pre-metamorphic thrust (Whately Thrust) that carries an older Littleton Fm. westward over younger Putney and Gile Mountain Formations has been advanced by Robinson and others (in Press) (see also discussion in Hepburn and others, 1984, p.142).

A few small porphyroblasts of light pink garnet can be seen in this outcrop. However, because of the high MnO content of these garnets, to 15.9 wt. percent, these rocks have been mapped as belonging with sub-almandine zone assemblages.

West of the abandoned chicken-yard a sequence of phyllites and feldspathic granulites similar to those at Stop 1 is exposed on the side of the hill.

Return to cars. Continue north on Route 5.

2.4 Road junction with dirt road on right, continue north on Route 5.

2.6 Roger's Construction Co. yard on right (east), possible alternate parking for Stop 2.

2.9 Dutton Pines State Forest.

3.4 Road junction with road to East Dummerston; continue on Route 5. Outcrop of Putney Volcanics to the west.

3.8 Road junction. Turn left (west) on road to East Dummerston and Dummerston Center.

4.7 Road junction in East Dummerston; continue straight.

4.8 Junction with road on right; continue straight.

4.9 Outcrop of Waits River Formation.

5.9 Dummerston Center. Turn sharp left (south).

6.0 STOP 3. Park along side of road.

NORTHFIELD FORMATION. Walk west to outcrops of the Northfield Formation exposed near the hinge area of the recumbent anticline above the Prospect Hill recumbent fold (see fig.1). The Northfield here is a gray, well-foliated mica schist with conspicuous garnet porphyroblasts and fewer porphyroblasts of biotite and staurolite. A few thin interbedded quartzites are also present.

Turn around; return north to Dummerston Center.

6.1 Dummerston Center. Turn left (west) on the paved road past fire station.

6.5 STOP 4. Park in road pull-off on north side of the road just before curve.

HINGE OF PROSPECT HILL FOLD, WAITS RIVER FM. & STANDING POND VOLCANICS. The Standing Pond Volcanics outline the northeasterly plunging hinge of the Prospect Hill recumbent fold at this locality (fig. 1). A 1/2 mile traverse will be made around this hinge by following the geologic contact between amphiboles of the Standing Pond Volcanics and schists, calcareous schists, and impure marbles of the Waits River Formation. This traverse presents an excellent opportunity to view a well-exposed hinge of a major recumbent fold. The contact is sharp and is easy to follow. The traverse begins just east of the pull-off near a very small creek along the eastern contact of the Standing Pond Volcanics. Follow this contact to the north through the woods and around the northeasterly plunging hinge of the recumbent fold, which closes on the lower south-facing slopes of Prospect Hill. Continue along the contact back southward (now the western contact of the Standing Pond with the Waits River). The paved road is again encountered about 1/4 mile west of the starting point.

Particular note should be made of the minor folds during the traverse. The most common folds are the F_2 generation, those formed congruously with the recumbent folding. These plunge NE and show a reversal of drag sense around the recumbent fold hinge; "M" folds are common near the axial surface of the major fold. A few F_1 minor folds that pre-date the recumbent folding, have the principal schistosity parallel to their axial surfaces, and are refolded by the F_2 folds, are visible in outcrops near the road.

If time and weather permit we will climb Prospect Hill for an excellent view from the open summit (perhaps lunch). Please be particularly careful on this traverse with litter and the indiscriminate use of hammers. We are able to make this stop only with special permission.

Return to cars; continue west on paved road.

6.7 Outcrops of the Standing Pond Volcanics in the hinge of the Prospect Hill recumbent fold.

6.8 Contact of the Standing Pond Volcanics with theWaits River Fm.

6.9 Junction with dirt road to south; continue straight on paved road.

7.4 Outcrop of aplitic dike associated with the Black Mountain Granite.

7.8 Junction with road from right (north); continue straight.

8.5 Road junction; turn sharp left onto dirt road.

9.3 STOP 5. Park by abandoned quarry buildings and follow path east to the abandoned Presbury-Leland granite quarry.

BLACK MOUNTAIN GRANITE. The Black Mountain Granite is a late synorogenic to post-orogenic pluton correlated with the New Hampshire Plutonic Series (Billings, 1956). It is commonly a very light gray, massive, two mica granite-granodiorite with small garnets as an accessory phase. Corundum (1-2%) is present in the norm (Hepburn and others, 1984). Note the weak foliation produced by the alignment of the fine-grained micas. Recently, Hayward and others (1988) obtained a Carboniferous crystallization age of 326 $\pm$ 17 Ma (Rb-Sr whole rock) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7118 $\pm$ 0.0008 for the Black Mountain. Previously, a Devonian age had been assigned to this pluton by Naylor (1971).

West- to northwest-dipping sheeting is well exposed in the quarry walls. Note particularly how the thicknesses of the sheets increases with depth.

STOP 5A. Walk northwest from the quarry to the banks of the West River where the contact of the granite with the surrounding Waits River Formation is well exposed. Dikes and sills of granite and aplite are abundant within a few hundred feet of the contact and likely indicate stoping as the mechanism for emplacement of the pluton. The dikes cross-cut bedding and the principal schistosity.

Some have a weak foliation roughly parallel to the regional schistosity but they clearly post-date the major deformation. The country rocks near the granite have been altered by contact metamorphism, in addition to having been regionally metamorphosed to the staurolite-kyanite zone.

Return to cars; turn around and retrace route north the the main paved road.

10.1 Junction with paved road; continue straight (north).

10.2 STOP 6. Park near the entrance to the covered bridge on the east side of the West River.

WAITS RIVER FORMATION. Outcrops typical of the Waits River Formation in the center of the Guilford dome are seen along the east bank of the West River under the bridge. The rocks are interbedded impure marbles, calcareous mica schists, and mica schists. Most of the minor folds present here are assigned to the F_2 stage and developed congruously with the large-scale recumbent folding. They were refolded into their present attitude by the rise of the Guilford dome.

Return to cars; proceed west across the covered bridge to Vt. Route 30.

10.3 Turn right (north) on Route 30.

10.8 Maple Valley Ski Area on left.

11.5 Outcrops of Barnard Volcanics on left, we will return to these after turning around.

12.2 Junction with road to Williamsville, just before bridge over Rock River. Turn around with care and return south on Vt. Route 30. (Note: garnet mica-schists typical of the Northfield Fm. are exposed on the south bank of the Rock River below the bridge.)

12.9 STOP 7. Park with care on the right shoulder beside large road-cuts.

BARNARD VOLCANICS. The Middle Ordovician Barnard Volcanics are exposed here in the Fall Brook anticline, which forms the core of the proposed recumbent anticline above the Prospect Hill fold (fig. 1). The anticline is overturned, with both limbs and the axial surface dipping moderately to steeply northwest. At this stop, the rocks include amphibolites and felsic gneisses characteristic of the Barnard. Minor amounts of rusty-weathering schist similar to those of the Cram Hill Member are also present in this anticline, but have not been shown separately on figure 1.

Continue south on Route 30.

14.2 Covered bridge on left; continue straight on Route 30.

14.9 Note Black Mountain and the granite quarry to the east across the West River.

15.3-.6 Outcrops of the Waits River Formation.

15.8 Iron bridge to left; junction of road to the right; continue straight on Route 30. Outcrops of granite in the brook to the west.

17.2 STOP 8. Park at side of Route 30 by the large road-cut on the right (west).

CONTACT METAMORPHOSED WAITS RIVER FORMATION. The Waits River Formation in the outcrop here, near the contact of the Black Mountain Granite, has been affected by contact metamorphism in addition to staurolite-kyanite grade regional metamorphism. Calc-silicates, particularly actinolite and diopside, are well developed in the impure marble beds. Diopside has not been observed in the Waits River Formation in the Guilford done area outside of the contact aureole of the Black Mountain Granite.

Continue south on Route 30.

18.8 Small roadmetal quarry in the Waits River Formation.

19.0 Outcrop of Waits River Formation.

19.7 STOP 9. Park at the left in the pull-off beneath the I91 overpass.

GILE MOUNTAIN FORMATION, MARBLE MEMBER. Exposures under the overpass are fairly fresh outcrops of the marble member of the Gile Mountain Formation, metamorphosed to the biotite zone. Impure marble beds (already starting to obtain the distinctive punky-brown weathering rind) similar to those in the Waits River Formation are interbedded with micaceous quartzites and phyllites. The marble member of the Gile Mountain Formation is similar in many aspects to the Waits River Formation except that it contains a higher percentage of quartzitic beds and occurs east of the Standing Pond Volcanics.

END OF FIELD TRIP

Continue south 1.5 miles to Brattleboro for junctions with major highways. To return to Keene, turn left (north) in Brattleboro on Route 5 and follow about 2 miles to the junction of Route 9 at the Howard Johnson Restaurant. Follow Route 9 east to Keene.